Surface and sub-irrigation out of doors, Bulletin, no. 34

Rane, F. Wm.

New Hampshire Agricultural Experiment Station

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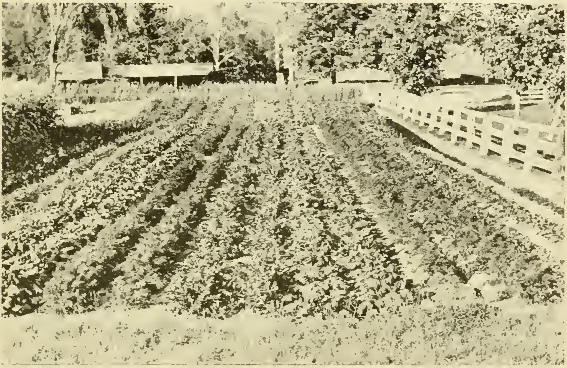
NEW HAMPSHIRE COLLEGE

AGRICULTURAL EXPERIMENT STATION

SURFACE AND SUB-IRRIGATION

OUT OF DOORS



IRRIGATED GARDEN

BY F. WM. RANE

NEW HAMPSHIRE COLLEGE

OF

AGRICULTURE AND THE MECHANIC ARTS

DURHAM, N. H.

NEW HAMPSHIRE COLLEGE

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AGRICULTURAL EXPERIMENT STATION

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HORTICULTURAL DEPARTMENT

Bulletin No. 34.—Irrigation

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SURFACE- AND SUB-IRRIGATION OUT OF DOORS

F. WM. RANE, M. S.

After Bulletin No. 33 of the West Virginia Experiment Station, "Sub-Irrigation in the Greenhouse," was issued, September, 1893, numerous inquiries came from various states asking for details in regard to special points, and particularly as to whether we had any experience or suggestions as to its application out of doors.

In regard to the application of sub-irrigation to out-of-door crops, we were without adequate data. Experiments have been pursued since then, looking toward a solution of the questions unsolved; and now, while we do not claim to be able to throw all possible light on the subject, nevertheless we feel that the practical ideas gained from three years' study and experimentation may be of interest and value.

In publishing this bulletin at this time, the main object is to cover the subject of irrigation in so far as it is of importance to that section of the country lying for the most part east of the Mississippi river; and with reference to small rather than large areas. If, by trial, it is shown that irrigation pays upon our higher priced land, as that of the garden, orchard, etc., the question as to its application on larger areas and cheaper land will naturally solve itself. The conditions in the section named differ widely from those in the so-called arid regions of the West. This bulletin is concerned only with the conditions prevailing in our own neighborhood.

The question of irrigation in the East is of late becoming more and more important. The past few years have been especially dry during mid-season, and where artificial watering has not been available, the various crops have necessarily suffered. This drouth, however, has not been caused by a lack of the usual precipitation, or rainfall, as is the case in the arid regions, for meteorological records show that the total rainfall has varied very little from year to year; but the cause of the whole trouble is the irregularity of the distribution of rain. This irregularity is attributed to various conditions, principal among them, perhaps, being the destruction of forests. The question now is: How can we best overcome these conditions? Irrigation seems to be the only alternative; hence we look to it for a remedy.

WHY DO WE IRRIGATE?

By irrigation we mean supplying vegetation with moisture when natural causes are not sufficient to produce the results desired. It is mechanical interference with nature for definite results. Until comparatively recent years few people east of the Mississippi were interested in this subject; the precipitation, or rain-fall, was comparatively regular, and one year with another was sufficient. The severe drouths, however, of the past few years, which have been so persistent, have burdened many people, and demand a remedy. People in some sections have actually lost money, should their time be counted of any value, in growing certain crops; and in most sections this drouth has materially cut crops short and therefore the profits, for it is almost as much work and expense to grow a partial crop as it is a full one.

In the arid lands of the West where the evaporation exceeds the precipitation, we easily see that irrigation must be resorted to; but this is not true of the East. Although in many states we do not know the exact excess of precipitation over evaporation, nevertheless the former is necessarily greater; this is not the point, however, for what we desire to secure is the even distribution of rain-fall. In the years containing some of our dryest summers, meteorological records show us that the average for the year is fully as great as in other years when the summer seasons have been ideal. Knowing these facts, gardeners, fruit-growers, and in a few cases farmers, are studying out remedies for themselves. It is not uncommon to see question after question in our horticultural papers seeking information on this subject.

In many sections land is too expensive not to realize considerable profit from it, and excessive cropping is necessarily being resorted to. In a dry season it so happens that much capital is lying idle, and it is a profitable investment that provides for irrigation. We irrigate, therefore, because we are compelled to in order to secure the best conditions for raising crops in a dry season.

SOURCE OF WATER SUPPLY

This question we cannot go into in detail. Where one person can secure water from natural springs or reservoirs, the majority are dependent upon wind-mills, hydraulic rams, steam-pumps, drawing in tanks or barrels, etc. This question is not as important to the general public, we feel, as the economical means of using water when it is available. By a little ingenuity, on the part of our gardeners and agriculturists, more or less water can be stored for a dry time. If by some means enough can be retained from our wet seasons to be used on small areas, as, for instance, from one fourth of an acre to four acres, or even less, the results will indicate whether it can be made a profitable investment or not. It is always desirable to have a good pressure or fall, if possible, as, even in subirrigation in the greenhouse beds, if there is no pressure or force to the stream, not nearly so good results are secured in the same time. Where no pressure is present, however, the same results can be obtained by having a slight incline, and checking the flow at various points. This is accomplished by damming up, if the irrigating stream be open, or by obstructing the flow by means of tins slipped between the joints, if irrigating by means of tile, removing and replacing the tins as the case demands.

The extensive operations in the West are dependent in most instances on a stream with considerable force and volume. Many of the reservoirs in our more central and eastern states will be on a less extensive scale, unless they are situated so as to use the water-works of cities. They will have far less pressure ; therefore the percolations will necessarily be more natural, and that water brought into contact with the soil nearer the surface will be the more available for the use of the plant, volume for volume. By using the tins already mentioned, the water can be easily controlled.

In some places it is possible to dam up small streams which run dry in summer, but during the wet seasons, as in the spring and fall, carry a great volume of water. This would be a comparatively easy task in many sections of this state, and not only in the more hilly sections. Recently, when visiting Massachusetts throughout the Cape Cod cranberry section, I saw reservoirs built on comparatively level land, which watered large areas in a short time; one in particular, that of Mr. A. D. Makepeace, an extensive cranberry grower, who, by backing

FIG. 2. VIEW OF COLLEGE RESERVOIR.

up a small stream with a strong dam about one hundred feet in length, is able to flood, if necessary, upwards of one thousand acres. The water supply at the West Virginia Agricultural Experiment Station gardens comes from natural springs in the mountains, six miles distant, and the Morgantown company incurs only the expense of piping it to the consumer, the natural fall securing sufficient pressure.

Figure 2 shows our own college reservoir. When the institution was located here a few years ago, the water supply was found to be inadequate, and a few acres of land were purchased lying on either side of a small brook, a short distance from the college. A dam, three hundred feet long, eighteen feet deep, and ten feet wide, was constructed, the water piped to the college grounds, and now we have an almost inexhaustible supply of water at a cost of two thousand dollars, exclusive of piping.

Professor Robinson, Horticulturist of the Maryland Agricultural College, told me of an instance where one man in his state built a wind-mill and large tank in the centre of his ten-acre trucking farm, who claimed that because he was able to irrigate, he had realized over and above ordinary returns, enough in two years to more than pay for his additional equip-

FIG. 3. COLLEGE FLORICULTURAL GROUNDS. IRRIGATED.

ment. One of the most practical methods of irrigation is that of Mr. S. S. Bailey, of East Paris, Michigan, an account of which was given in *The Rural New Yorker*, February 9, 1895. A small brook was checked by a dam eight rods long, six feet high, and broad enough on top to drive a team, thus making a pond covering three-quarters of an acre. Mr. Bailey claims to be able by proper husbanding to relieve from drouth from fifty to eighty acres, as well as to raise the maximum of the crop. Under head of results in a dry season, he writes that the comparative results with sweet corn were as $10 is to $93, not taking into account the extra fodder obtained. With field corn, in 1894, more was raised on three acres of irrigated land than upon twenty not irrigated. Strawberries were "a wonder to all who saw them"; cabbage plants made heads "too large to suit the groceryman to sell at retail." Irrigation allowed double cropping; after the corn, the ground was given up to rye, which was sown during the last cultivation of the corn and which gave excellent green pasturage for cows and sheep until late in the season. Mr. Bailey says: "As now controlled and utilized for irrigation, at a low estimate, we consider it worth more to us than an investment of $5,000 at six per cent. annual interest."

I know of one instance where a farmer has taken advantage of a natural spring, which comes out of a bank. By excavating slightly and building a rough stone work about it, he has sufficient water for his barn-yard stock, which drink from a trough into which the overflow runs,—and for a small garden. It also supplies ice for his own use. A unique method of irrigation was called to my attention last summer by a lady who had devised it. It was nothing more than old eaves-troughs extending from the house to the cucumber patch in the garden, which carried the superfluous water of the kitchen to assist the cucumbers.

These are but few instances; many more could be cited. Two prominent farmers, whom I know, have each backed up small streams for fish ponds in summer and for ice in winter. In both cases these are at sufficient elevation to irrigate nearly half their farms, should they enlarge their capacity; but I doubt if the farmers have ever thought of doing it.

ECONOMY OF WATER

The object of all systems of irrigation is to place water at the service of the plants, and that system which does this most effectively, and at the same time is most economical, is the best. With the flooding or furrow systems of irrigation it is estimated to be a day's work for one man to irrigate from one to five acres; and in order to prevent loss from evaporation this system demands excessive cultivation. Even then the loss is great.

With the latest, or sub-irrigation, method, which has been so successful both in the greenhouse and out of doors during the past few years, we have a system, which, as its name signifies, applies the water to vegetation from beneath through pipes laid below the surface of the ground,* and, in case of out-of-door irrigation, at a depth beyond the reach of the plow†. The ground is watered by capillary attraction. These pipes are used indefinitely from year to year. One of the advantages claimed for sub-irrigation over surface-irrigation is the economy of water. Some advocates say that it does better work with half the water, while others go so far as to state that it saves from three fourths to nine tenths. In our own experience, as far as the greenhouse is concerned, when we have water-tight bottoms in the benches, there is no question as to its saving both water and time. But from experiments carried on during the past two years, we have found that the percentage of water saved is greatly reduced when this system is applied to out-of-door crops, and even to crops in the greenhouse where the water-tight beds, or those practically so, are not used.

EXPERIMENTS IN GREENHOUSE

To test this point as to greenhouse beds, an experiment was conducted by myself during the season of 1893–'94. at the West Virginia station. Two beds, each eight by fifty feet, were made, in each of which three rows of tile were placed equidistant and running lengthwise of the bed. The conditions of each bed were similar except that one had a perfectly water-tight bottom of matched flooring, while the other rested on the ground. The soil, method of watering, etc., were the same. The ground upon which the bed rested was a reddish, hard clay, which had been unused until the soil was put in. It had become very hard and dry from the heat in the house; in fact it made such a good walk that we did not cement it until it began to show wear. After watering a few times we noticed that the moisture was not sufficient in the latter bed, and we were compelled to resort to surface-watering. However much

* Agr. Science, Vol. vii, page 383.
* West Virginia Expt. Station, Bulletin 33, Vol. 3.
* Ohio Station Bulletin, Vol. V., No. 6, page 101.
† American Gardening, Nov. 10, 1894.

water was used, capillary attraction was not sufficient; on the other hand it soaked through the clay and even moistened the hard, dry walks on either side. The bed containing the water-tight bottom worked perfectly from the first. This, therefore, showed that it was not altogether the fault of the soil.

To prove the above further, we took a section in the center of the bed on the ground, five feet in length and eight feet in width,—the width of the bed. It was separated from the rest of the bed by board partitions, at the bottom of which notches were cut to accommodate the three rows of tile. We removed an inch or two of the soil from the bottom of this section, replacing it with cement. We also cemented the sides and around the notches in the partitions, thus making the bed practically water-tight. This section was watered with the same flow of water as the rest of the bed, the only difference being that when the water was emitted into the soil, it could not soak through the bottom. The result in every instance was that if sufficient water was applied for the cemented part, the remainder of the bed received very little.

On the other hand if enough water was poured in the tiles for the two ends of the bed, the cemented portion became muddy. It is evident that if the sub-irrigated beds contain a tight bottom the saving of water is very great; but with some soil bottoms, a greater percentage of water is lost by soaking through the ground than could possibly have gone off through evaporation in surface irrigation.

EXPERIMENTS OUT OF DOORS

Knowing the results of this experiment in the greenhouse, and the good results reported from other sources with this system out of doors, we arranged our grounds for testing it. Realizing that celery is a crop that demands water on high land, we arranged to water it in rows in this method, the tiles to be placed at a depth to be missed by the plow.

Good results were secured from this system from the growing plants, but the saving of water was not nearly as great as claimed by other experimenters. On examination we found that, as in the greenhouse bed without the water-tight bottom, a great quantity of water escaped deep in the soil and ran off in the drains, while the soil was not even moist for some distance below the surface. In our soil it was a hard matter to determine what was the limit for beneficial results. The tiles being out of sight, it was difficult to tell whether they were distributing the water evenly; also there could be no doubt as to the extravagance of this method with water.

A NEW IDEA

Realizing the defects of the above system and the demands for a still more practical one, we studied the existing conditions

FIG. 4. THE METHOD OF IRRIGATING ON A LARGE SCALE IN THE WEST.

with the idea of improvement. The objection to surface irrigation, then, is waste of water in evaporation, some horticulturists claiming that in very hot weather five sixths goes off in the air; therefore, in order to get benefit of one sixth, we must apply five times as much more. Whether this is true or not, we do know that a great quantity of water is necessarily lost by this method.

In one of the late issues of a prominent horticultural paper the writer says, "In determining the depth at which the tile should be laid, * * * at no place should the tiles be so near the surface, that they will be disturbed by the plow." We can see that this is true, perhaps, of some soils but it is not true in all cases.

Since we found that sub-irrigation could not be depended upon as an economizer of water on account of seepage, and since in surface irrigation there is a great loss of water through evaporation, we could see no reason why the use of the tiles could not combine the good points of both methods by placing them near the surface. The objection to their being placed above the reach of the plow would be overcome by the fact that they could easily be removed, if necessary, when the crop was harvested. Accordingly, experiments to test this arrangement were carried on at the West Virginia Station the past two years with satisfactory results.

As this new method of irrigation contains all the commendable points of both surface irrigation and sub-irrigation, I deem it worthy of consideration. It approaches much nearer an ideal system for economizing water,—doing away with the great loss by evaporation in surface irrigation and by seepage in sub-irrigation. Also, since the tiles are above the greater mass of the roots, the water that does soak away is at the command of the plants.

SURFACE IRRIGATION

Where plenty of water is available we believe the best and most satisfactory results are secured by applying the water where needed through ditches. The ditches are easily and quickly made with plow, cultivator, or hoe; they cost only the time of making, are easily checked at any point, and the operations are under known and visible conditions. There is no obstruction either below or above ground to hinder cultivation; there are neither pipes nor tiles to be stopped or clogged by roots or foreign matter. While more or less evaporation is going on, this is easily overcome to a certain degree by judiciously cultivating and applying the water during the cloudy portions of the day or in the evening. What water does enter the soil is available and effective, and, assuming that the ground is already well drained naturally or artificially, the conditions are the best. The shallow-rooted plants are always directly benefited, while the deep-rooted ones derive some good. They, however, are not always in as great need of moisture even in dry weather. Good results from surface irrigation also depend upon the surface soil; purer sandy soils are not retentive of moisture, while the stiff clays are particularly so; therefore soils such as the loams are much preferable.

Figure 3 and the frontispiece show sections of both floricultural and olericultural or vegetable gardens on the college grounds, which have been watered for the most part by surface irrigation. In Fig. 3 the average depth of soil was not over six inches on account of underlying ledge, but by proper fertilization and irrigation through a net-work of small ditches made and manipulated by Mr. Hunt, the assistant horticulturist, the beautiful effect here shown was accomplished. In the frontispiece, the conditions were about the same except that the soil was very much deeper. The outer rows, or the rows next the fence in this cut, show very plainly the effect of lack of irrigation. The lower ends of these rows together with the rest of the section were watered by surface irrigation. The furrows for the distribution of water were shaded by the foliage in both of the cuts and, too, at the time when the sun was hottest and the drouth severest, and evaporation was thus partially prevented.

There are many instances where surface irrigation will be found the most economical, not only where plenty of water is to be had, but where economy of water is necessary. There are more advantages in favor of this method than are attributed to it. After having experimented with sub-irrigation at various depths and upon different soils, I would recommend caution before going into irrigation on a very extensive scale, believing that the extra expense in purchasing and laying tiles will more than offset the expense of labor in surface irrigation. Figure 4 shows the method of surface irrigating or flooding in the West.

SUB-IRRIGATION

Doubtless there are soils in which sub-irrigation—watering through pipes laid beneath the surface—would be more economical than any other method of irrigation. Theoretically it appeals to the mind as being an ideal system. One writer says: "If properly carried out the system has many advantages over any of those using surface irrigation. Among them may be noted economy of water, as its advocates claim that it does better work with less than one half the amount of water, while some go so far as to claim that it saves from three fourths

FIG. 5. LAYING TILES FOR IRRIGATION, W. VA. UNIV. GARDENS.

to nine tenths. When the flooding or furrow system of irrigation is used it will be a day's work for one man to irrigate from one to five acres, but with sub-irrigation he will merely need to turn on or shut off the water from the different portions of the systems of tile, and while the irrigation is going on can busy himself about other duties."

The misleading feature of this system of irrigation comes from the difference among the soils; hence, unless the operator has an experimental knowledge of his own conditions, his chances of failure are great. A physical and mechanical knowledge of the soil is necessary before one enters upon large operations. Some soils absorb and retain moisture readily while others do not. Even in sub-irrigation in the greenhouse beds, where we have studied this subject most, we found that some soils although carefully prepared for the indoor beds, were slow to absorb moisture through capillarity unless the beds in which they were placed were water-tight. Some greenhouse soils need watering daily ; others, such as those of mucky consistency, need it but rarely.

Where sub-irrigation will work well out of doors it is an ideal method of watering. Some of the points in favor of it are as follows :

1. The surface soil never bakes or surface hardens.

2. Plants run very evenly.

3. The soil can be worked at any time and thus be kept in better condition.

4. It is claimed that less water is required.

5. The pipes or tiles serve both to water the beds and retain the excess of moisture.

6. The openings underneath the soil allow free access of air ; hence soil never becomes sour or stagnant.

7. Surface evaporation is slight.

8. Fungous diseases are not so prevalent.

LAYING THE TILES FOR SUB-IRRIGATION

Laying the tiles for sub-irrigation necessitates a knowledge of many of the points already considered. On very rolling ground it is necessary to follow the contour of the slopes, giving the tiles a drop of about one inch in one hundred feet if in long runs, or if in shorter lengths a slighter grade (see Fig. 5). The distance between the rows of tile varies with the nature of the soil and sub-soil, depth laid, and kind of crop to be grown. Usually tiles are placed from 6½ to 40 feet apart, depending upon whether they are to be used for the vegetable and flower garden or for the orchard and farm. The depth generally recommended is from any distance below the reach of the plow to two feet below the surface. When the proper excavations have been made, the same methods are employed as in determining the proper level for ordinary tile drainage. One must understand just how to lay the tiles so that the ends may not be either too far apart or too close together, depending upon the slant of the tiles and the nature of the soil. An inexperienced person might better get an idea of this by first laying a line upon the surface and, by pouring water through it, study its action. Should there be danger of the tiles bursting from freezing during the winter a proper drainage should be given at certain points to draw the water off in the fall. By taking advantage of this drainage the excessive moisture in the soil in spring, and after drenching rains, can also be drawn off.

The tiles can be so laid that the water is applied through a single main feed-pipe; or, by running the pipes above ground at the end next the hydrant, each row may be watered separately. The latter method requires a number of hydrants at convenient distances along the garden so that pieces of ordinary garden hose will reach all lines of tile. In order to get the best results in the former case the ground should be nearly level.

Even then still better results are secured by having not over one half acre in each system, and a number of these systems rather than one large one. The main feed-pipe should be not less than two inches in diameter for an acre of land when applied through a single system. This should be enlarged as the area and number of systems increase. Where the practice is to water a number of lines at the same time, a proportionately larger supply pipe is needed. A one-inch pipe answers for areas not over one half acre, a two-inch for an acre, and a proportional volumetric increase as the area is enlarged.

The reservoir should have sufficient capacity to irrigate the area under consideration. In order to cover an acre of ground to a depth of one inch, it requires 3,630 cubic feet of water which is equivalent to about eight hundred and fifty barrels. A similar quantity should be provided for sub-irrigation. If the ground becomes very dry, it is advisable as in surface irrigation to use the maximum quantity to get beneficial returns. If the surface is frequently cultivated, the loose soil prevents evaporation and hence lessens the number of applications in a dry time. By watering frequently rather than waiting until all the reserve water is needed, only a portion of it will be required and there will be a constant supply on hand; for as in the case of a windmill, during the dryest time the wind does not blow regularly even on the sea-coast.

A NEW METHOD OF IRRIGATION

An account of this was given by myself in *Garden and Forest*, December 5, 1894, and again in *The Rural New Yorker*, June 1, 1895. The plan recommended was about as follows:

Try irrigation by simply placing the tiles slightly in the surface of the ground, or at any convenient depth; give them a slight incline, this varying according as you have pressure or not. In most cases, the water is scarce, and the object is to get it to the roots of the plants with as little waste as possible.

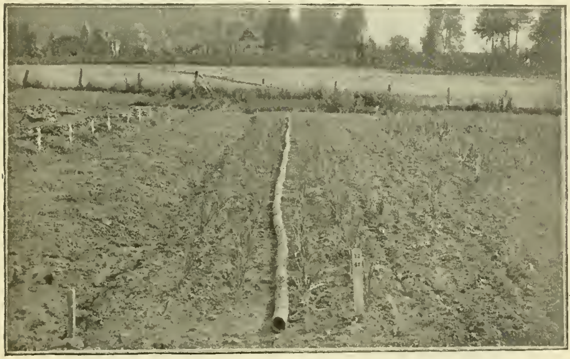

FIG. 6. ONIONS FROM SEED WITH AND WITHOUT IRRIGATION.

The plan followed by us last year was to place common, porous two and one-half inch drain tiles in a continuous row, end to end, on the surface of the soil, and vegetables were planted on either or both sides of the line. The tiles were one foot long, and by pouring in the water at one end of the line it was distributed at the joints throughout the length desired, when the opposite end was stopped up. Take celery as an example crop for irrigation on uplands. We plant the celery as above stated, Fig. 6, and while it is young we have simple surface irrigation ; but as the crop grows, we bank it up, and finally have the tile covered, and thus have sub-irrigation—Fig. 7. The tiles are cheap and last indefinitely. When the celery is harvested, the tiles are dug out also and piled up, or used for sub-irrigation in the greenhouse beds. Potatoes and various other crops can be grown in the same way. The celery watered this year grew well, and did not rust. Besides this, we were able to water twenty times as much space in the same time as in the ordinary way with ditches. Besides saving time, this plan delivers water where it is most needed, and we have reason to believe, is fully as economical with water as with time.

Rows of celery watered in this manner were planted in a potato field, leaving every other space between the potato rows vacant, so that two rows of potatoes could be dug together when ripe. Besides watering the celery, the moisture reached the tops of the potato hills, as was plainly seen every morning by the dampness of the surface throughout the intervening space, thus showing that the watering was sufficient for at least three feet and three inches on each side, or six feet six inches in all, the rows being three feet three inches apart. Where the rows were on a slight incline, we slipped a piece of tin between the joints, and held the water where it was needed ; then, by pulling it out and inserting it further down, another section could be treated. The sections can be made longer or shorter, according to the angle at which the ground inclines. This subject is receiving our attention this year, and we hope to be able to present it more fully at a future time.

As already stated the work was continued last year at the West Virginia Station, and as is shown in Fig. 5 considerable area was used for testing this system. Last year, however, proved to be a very poor season for this purpose ; shortly after the plants were set out, they were caught by a frost and again a second transplanting was nipped, which rendered it too late in the season for natural conditions by the time the third planting came on. The season was exceptional also for the reason that the rainfall was comparatively well-distributed there, and therefore little irrigation was needed. In the case of onions on high ground very fair results were shown in favor of those irrigated.

Fig. 6 shows the comparative results where seed was sown upon upland,—with and without irrigation. As shown in the photograph, the row of tiles was simply laid upon the soil and used as a quick conveyance of the water to the soil, the water entering the upper end of the tile through ordinary garden hose con-

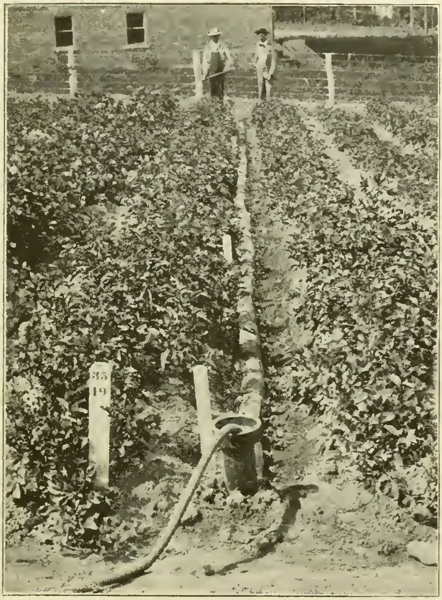

FIG. 7. IRRIGATING CELERY; THE BEGINNING.

nected with the hydrant. We found also that the tiles when laid lengthwise in the old-fashioned garden bed, where the rows run crosswise and comparatively close to each other, assisted greatly in rapid watering. Where celery is grown in beds for self-blanching the same method of watering is very advantageous.

This system is a combination of both the sub-irrigation and surface irrigation systems and the points claimed are:

1. It is a great economizer of time in watering.
2. It saves water.
3. It applies water where the plant cannot but help receiving benefit from it.
4. It is simple, practical, and inexpensive.

EXPENSE

This is the vital matter, and any system of irrigation will decline in use should it prove to be beyond the reach of the average farmer. What is most desired at present is a system of irrigation that will be efficient and at the same time inexpensive. The reason, doubtless, that more experiments have not been carried on in the eastern United States is on account of the great amount of time, labor, and money required to put forth proposed plans,—with the uncertainty of beneficial returns. Where conditions do not favor the formation of a company for the erection of a reservoir sufficient for all, the individual must irrigate to the best of his circumstances. For this reason surface irrigation by the furrow system is popular where water is at hand, for many can give the great amount of labor necessary but are unable to expend the money required for the cement pipes, tiles, etc.

The cost of the reservoir or source of water supply will be the same regardless of the method of application. It is important that it be adequate for the area used, which for general purposes is a minimum of eight hundred barrels per acre for one good application in a dry time. If this amount can be replenished by pumps, springs, etc., at frequent intervals, a reservoir of this capacity will be large enough, but should the operator depend upon one general supply, a proportionately larger one will be needed. A wooden reservoir for any considerable area would be quite expensive, and it will be only where good returns are depended upon from small areas that these are profitable. A 7,200 gallon reservoir at Durham, made of cypress or Georgia pine, was built at a cost of ninety dollars, which did not include connections and foundation.

Natural reservoirs can usually be made at less expense and are fully as durable. By puddling the bottoms and sides seepage can be prevented as well as by cementing, and the cost is far less. These reservoirs should be on the highest spot so that a slight fall may be secured from it to all parts of the grounds. The cost necessarily varies in each instance; therefore I will not attempt to give detailed expenses of reservoirs.

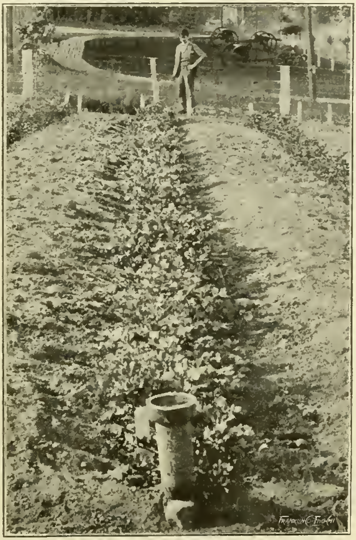

FIG. 8. IRRIGATING CELERY; TWO-THIRDS GROWN.

The cost of conveyance of the water from the reservoir to the ground will vary as to the distance the water is to be carried as well as the method of conveyance. If through open ditches the expense is simply in the amount of labor, which is only that employed in making the main ditch. This should be built with the sides thrown up so as to bring the bottom on a level with, or a little above, the surface where the water is applied. The size of the ditch must conform to the slope and amount of water to be carried in it. Where pipes are used the cost will vary according to their diameter and kind of material used.

The cost of the tiles and the expense of laying them for distribution in sub-irrigation is said to vary from twenty-five to forty dollars per acre. Where they are laid near or on the surface as described under head of "New System," the only expense practically is that of the tiles, as the laying of them is a very simple matter. The tiles, size two inches, cost about fifteen dollars per thousand, and the three-inch about twenty dollars. The expense of course is in proportion to the number of tiles used. Test them on a small scale at first and find out whether you would be benefited by the extra expense. Should they prove a success more can be used; if a failure the tiles are always a good investment for drainage.

Cut 4 shows the method of surface irrigation. A slope of six inches in every one hundred feet is considered a good flow for furrow irrigation, while one foot to the hundred is about as much as one can handle.

CULTIVATION

To get the best results cultivation goes hand in hand with irrigation. It is a necessity for plant growth; it not only keeps the weeds down but gives better ventilation, more sunlight, and reduces the amount of evaporation from the soil. Frequent shallow cultivation, say once a week or thereabouts, retains the moisture in the soil sufficiently many times to bridge over short drouths. It should be begun as soon after a rain as the land can be worked. By deep plowing, which may mean subplowing in some cases, together with the cultivation already mentioned for cultivated crops, and proper cultivation before planting with other field crops, the plants will withstand a comparatively severe drouth before demanding irrigation. The more one can counteract drouth by proper cultivation, therefore, the less the number of applications of artificial watering. The only thing to be understood is that when artificial watering is necessary to secure desired results, the supply should be adequate, which means, as already stated, one barrel (thirty-two gallons) per tree, or five hundred to eight hundred barrels per acre. Stop cultivation when the proper time comes, which ordinarily is also the best time to stop irrigation.

MULCHING

This is nothing more than another kind of irrigation in a milder form. The mulch used retains moisture which in a dry time protects the ground from drying out so readily, thereby benefiting the plants. Mulched strawberries in the season of 1894 withstood the drouth while others died; also those mulched and irrigated as well did not require as much water and gave better results than those irrigated and not mulched.

Tomatoes mulched in 1895 and not sprayed gave fully as heavy yield, accompanied by a far less amount of rot. The results from mulching depend more or less upon the season, but it is believed we can well afford to give it more attention, especially in our gardens.

GENERAL CONSIDERATIONS

In order to obtain a comprehensive knowledge of irrigation we must have a similar knowledge of drainage. There is evidently a close relation between the two, and just how elastic it is no one knows. There are many soils that perhaps would be more productive were they tile-drained instead of demanding artificial watering; others have a natural drainage and need more moisture, while still others would yield better returns with both drainage and irrigation provided. Soils differ in the absorption and retention of moisture. Water held in the soil by capillarity is better suited to supply the plant than free water which flows under the action of gravity. The main principle is that, whether naturally or artificially, enough water must be supplied, but not so much that it will stagnate and induce conditions unfavorable for plant growth.

The conditions for practical success in irrigation are as follows:

1. Reservoirs of good water, natural or artificial.
2. A sufficient descent from the reservoirs to the place of distribution; the more pressure, the better.
3. Proper soil.
4. Experience and good judgment in application.

LITERATURE ON IRRIGATION

For general literature on this subject, see The Third Annual Report of the Colorado Agricultural Experiment Station, 1890, pp. 78, 79, which gives a list of 71 works on irrigation with brief comments on the character and the scope of each; also for statistics and cost of irrigation works, same report, pp. 71–78.

More or less has been done in other states, as for example, California, Nebraska, Arizona, Utah, Wyoming, Louisiana, Wisconsin, Kansas, and New Jersey, reports of which may be found in the Experiment Station bulletins.

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SUMMARY REMARKS

1. We irrigate because we are compelled to in order to secure the best conditions for raising crops in a dry season.

2. Apply enough water when irrigating to do some good; a pailful applied now and then in a dry time is useless.

3. By being able to irrigate when a crop is nearly matured, we have a first-class crop, where otherwise would be an inferior one.

4. Ground beds in the forcing house, watered from the same row of tiles, with all conditions the same excepting that part of the bed had a water-tight bottom while the remainder did not, gave good results in the former case and very poor in the latter.

5. Experiments with celery upon a clay loam, with water applied both through ditches for surface irrigation, and through tiles below the reach of the plow for sub-irrigation, showed that the latter system required much more water than the former for the same results.

6. By taking advantage of the cloudy portions of the day

and as well the shade from the foliage of the plants, the loss from evaporation in surface irrigation is greatly lessened.

7. The percentage of water saved in sub-irrigation out of doors is greatly reduced on account of its soaking off in the soil below.

8. The fact that the tiles are out of sight and their action unknown makes ordinary sub-irrigation a little uncertain.

9. Sub-irrigation out of doors, where it works well, is an ideal system of watering.

10. If possible have a good pressure or fall.

11. Experiments for two seasons have shown that when the tiles were placed near the surface of the ground, the plants did fully as well as in the other systems and with less water.

12. By placing the tiles near the surface, the great loss by evaporation was overcome. This system also placed the water where even the shallow-rooted plants could not fail to receive it. It also combined all the good points of deeper sub-irrigation.

13. Three thousand six hundred and thirty cubic feet, or about eight hundred barrels, of water is the amount estimated to cover one acre of ground to a depth of one inch,—the amount recommended per acre for reservoir capacity.

14. Onion seed sown upon upland, with and without irrigation, gave marked results in favor of irrigation.

15. To get the best results cultivation goes hand in hand with irrigation.

16. Mulching and sub-soiling are milder forms of irrigation which can be resorted to with good results to counteract drouth.

17. Many soils need drainage, perhaps, rather than irrigation, while in some others there is a medium, which gives best results.

18. Under existing climatic and meteorological conditions, irrigation solves a very discouraging problem.